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REFERENCE COPY

Report No. DPS/TW-414/1

AUTOMOTIVE DIVISION

FC
BAC

REPORT ON INVESTIGATION OF THE RESISTANCE OF
1-INCH ROLLED HOMOGENEOUS ARMOR PLATE OF
VARIOUS HARDNESSES TO ANTITANK MINE ATTACK (U)

First Report On Ordnance Project TW-414

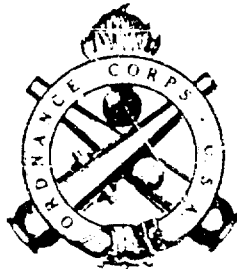
(D. A. Project No. 548-03-001)

(AD-1267)

W. V. RESNICK

MAY 1959

Aberdeen Proving Ground
Maryland



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DEVELOPMENT AND PROOF SERVICES
ABERDEEN PROVING GROUND
MARYLAND

ADP. RM. 1. ORDMC-RM.1

Capt WVRennick/ch/28264
7 May 1959

INVESTIGATION OF THE RESISTANCE OF
1-INCH ROLLED HOMOGENEOUS ARMOR PLATE
OF VARIOUS HARDNESSES TO ANTITANK MINE ATTACK (U)

First Report on Ordnance Project No. TW-414

Dates of Test: 29 July to 9 September 1958

ABSTRACT (U)

Twenty-three 1-inch-thick rolled homogeneous steel armor plates of various hardnesses having welded crack-starters were tested against 20-pound Composition B-loaded land mines, at a standoff distance of 17 inches. All of the plates were of Army armor except six which had a hardness level of 262 Bhn. These six plates were of STS steel usually designated as Navy armor.

Steel blocks were used as crack-starters and each measured 2 inches square by 3 inches high and was welded centrally on the top surface of the test plates by a single weld pass with a ferritic type electrode. The welds securing the crack-starter blocks were dye-checked to insure against the presence of weld cracking before testing. Each plate was positioned for test on a test facility to simulate mounting as a floor plate in a combat vehicle. All tests were conducted within a temperature range of -40°F and 0°F. Damage occurring to each plate was recorded.

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1. (U) INTRODUCTION

A number of tests have been conducted in the past to determine the amount of protection provided by cross-rolled homogeneous steel armor plate of 1-inch thickness against antitank mine blast.

This test was conducted to determine the protection provided by 1-inch-thick rolled homogeneous Army armor of various hardnesses, and STS (Navy armor) against land mine blast when the plates are conditioned to low temperatures. It was expected that the results would provide a basis for selecting the best hardness level for rolled steel Army armor floor plates and provide a comparison with STS (Navy armor).

2. DESCRIPTION OF MATERIEL

2.1 (C) Plate

The plates under test consisted of 1-inch-thick cross-rolled homogeneous steel armor having over-all dimensions of 60 by 84 inches. Six plates were available for testing in each of the hardness levels of 363, 262, and 255 Bhn while only five plates were available at the 302 Bhn hardness level. The physical and chemical properties of the test plates are listed in the manufacturer's test report contained in Appendix F. All plates were Army armor except the six at a hardness level of 262 Bhn. These six plates were STS (Navy armor).

The test plates were numbered consecutively on the upper left hand corner of the photographs, one through twenty-three, inclusive. The plates as referred to in this report will be identified by those numbers instead of using the photograph numbers.

The Brinell hardness and plate identification are as follows:

<u>Armor Type</u>	<u>Brinell Hardness</u>	<u>Plate Number</u>
Homo Rolled (Army)	363	1 through 6
Homo Rolled (Army)	302	7 through 11
Homo Rolled (Army)	255	12 through 17
STS (Navy)	262	18 through 23

2.2 (U) Land Mines

The land mines were molded at this installation into cylindrical shape measuring approximately ten inches in diameter by four inches in height with an over-all weight of approximately twenty pounds. The mines were uncased Composition B explosive, Lot No. HOL-7-180.

Also included in the mine was a recess to seat a tetryl pellet.

3. DETAILS OF TEST

3.1 (U) Procedure

A steel block measuring 2 inches square by 3 inches high was placed centrally on the top surface of the test plate and fillet-welded by a single pass with a ferritic type electrode around the perimeter of the block (Sketch 1, Appendix B). The fillet welds were then machine-ground to a smooth finish and dye checked to insure against weld cracking.

Two thermocouple leads were welded to the bottom surface of each test plate using silver solder. The thermocouples were located at points approximately eleven inches in from the long edge, thirteen inches in from the short edge and at opposite corners of the test plate (Sketch 2, Appendix B). In addition, two steel rods measuring approximately 1/4 inch in diameter by 3 inches in length and bent into an "S" configuration were also welded at points approximately one inch from the above-mentioned thermocouples. These "S" hooks were placed adjacent to the thermocouples to act as anchors to prevent the thermocouples from breaking off at the weld during final hookup (Sketch 2, Appendix B).

The plates were tested individually in the following manner: a test plate was placed on top of two steel beams measuring approximately twelve inches square by sixty inches in length, with the beams resting on the ground. The distance between the two inside edges of the steel beams was approximately fifty-eight inches. A steel frame weighing approximately three and a half tons was then placed on top of the test plate and squared to insure even coverage.

The frame was then filled with approximately 650 pounds of dry ice. The ice was pulverized by the use of a sledge hammer and spread to give even distribution. It is estimated that approximately 70% of the top surface of the test plate was covered by dry ice.

A tarpaulin 12 feet square was then placed over the entire setup to act as a blanket to assist in lowering the test plate temperature.

The temperature of the test plate was recorded by the use of a constant temperature recording device, connected to the thermocouple leads. For each of the plates tested, plate temperature was lowered 20°F below the actual temperature at detonation time. The 20°F differential was necessary to allow for final preparation before detonation. This preparation consisted of removal of the tarpaulin and dry ice, the placement of the 8-ton hold-down plate centrally on top of the frame, the positioning of the mine beneath the test plate and the final hookup of electrical detonating wires.

A mine was then positioned centrally under the test plate in a pre-dug hole leaving a distance of 17 inches between the top surface of the mine and bottom surface of the test plate. After completion of all necessary safety checks the tetryl pellet and electrical detonating cap were inserted into the mine and the mine was then covered with approximately three inches of loosely packed soil. Upon return of the explosive operator to the bomb-proof, the electrical detonating wires were connected to the detonating machine.

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When the temperature of the test plate reached the required level, the charge reached the desired temperature. After the charge was deformed, it was removed from the electrical detonating and machine. This procedure was repeated for the deformation of each plate.

The desired information and as to the deformation was recorded from the test plates. Photographs were taken to show the test results. Graphs, photographs, and other data are included in Appendices I, II, and III.

The twenty-three plates were tested in the sequence required by the "Program for Testing of Plates" under "Plate Three," Appendix C.

Throughout the conduct of the test, the temperature, pressure, shock-starters, application and distribution of the dry ice and the position of the plate was kept identical to maintain uniformity for the examination.

3.2 (a) Results and Observations

The detailed results of the tests are shown in the charts and graphs of plates Nos. 1 through 23. The results are shown in the charts and graphs of plates Nos. 1 through 23. The results are shown in the charts and graphs of plates Nos. 1 through 23.

The test results of plates Nos. 1 through 6 inclusive (Chart No. 1) with a hardness level of 245 HBN gave inconsistent performances. Plates Nos. 1 and 2 which were tested at -20°F withstood the mine blast and developed no cracking. Plates Nos. 3, 4, 5, and 6 which were tested respectively at -10°F , -20°F , -30°F , and -40°F all developed extreme failures which included disintegration of sections of the plate material.

The performance of plates Nos. 7, 8, 9, 10, and 11 (Chart No. 2) with a hardness level of 255 HBN was not entirely consistent. Plates Nos. 7, 8, 9, 10, and 11 which were all tested at -20°F withstood the mine blast in two cases and developed extreme plate failure in the other two cases. The results are considered to indicate that -20°F is the critical temperature for failure under mine blast for plates of rolled armor. At temperatures of -10°F or above it might be predicted that no failures would occur but this should be confirmed by actual tests. The performance of test plates Nos. 12, 13, 14, 15, 16, and 17 (Chart No. 3) with a hardness level of 255 HBN was considered to be generally consistent. Plates Nos. 12 and 15 ruptured at a temperature of -30°F . Plates Nos. 13, 14, and 16 which were tested at -20°F gave the cases of no failure and one case of extreme rupture. Plate No. 17 tested at -10°F did not develop any cracking. These results seem to indicate that -20°F is the approximate critical temperature for initial failure on plates of the 255 HBN hardness level.

Test Plates Nos. 18, 19, 20, 21, 22, and 23 (Chart No. 4) consisting of 375 armor with a hardness level of 265 HBN showed better performance in defeating mine blast than all of the other groups of plates tested. All six plates showed very consistent results as related to

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temperature. Plate No. 20 tested at -40°F ruptured but not as severely as some plates in the other groups which were tested at -30°F and -20°F . Plates Nos. 18, 19, 21, and 23 were tested at -30°F with plate No. 18 showing no rupture, plate No. 19 showing only slight cracking, plate No. 21 developing a rupture but not to an extreme degree, and plate No. 23 showing no cracking. Plate No. 22 tested at -20°F did not develop any cracking. These results for the group of STS (Navy armor) plates indicates this is the best material under low temperature conditions to withstand land mine blast.

3.3 (U) Charpy Data (Reference PTL Report No. 58-P-40, Appendix E)

Lower hardness readings were obtained at this installation for the majority of the plates, particularly those of the low hardness groups, than were reported by the armor manufacturer.

The results of the Charpy impact tests performed at APG indicated that the majority of plates met or exceeded specification requirements. Only four plates, Nos. 3, 4, 5, and 6 in the high hardness group, showed Charpy values slightly below the specification requirements.

4. (C) CONCLUSIONS

Based on the results of this test it is concluded that:

- a. Combat vehicle 1-inch rolled steel floor plate material of the STS (Navy armor) type provides better protection when tested at low temperature against the blast from a 20-pound Composition B land mine than rolled homogeneous Army armor at any hardness level from 255 to 363 Bhn.
- b. The performance of the groups of plates tested at low temperatures against mine blast may be ranked as follows:

<u>Numerical Rating</u>	<u>Bhn Hardness</u>
1	262 STS (Navy)
2	302
3	255
4	363

5. (C) RECOMMENDATIONS

Based on the results of this test it is recommended that:

- a. A project be inaugurated to thoroughly investigate the performance of 1-inch STS (Navy armor) at temperature levels from ambient to -40°F against land mine blast to establish definitely whether this material should be selected as a floor plate armor.

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- b. Until STS (Navy armor) has been definitely proven a desirable floor plate material at all service temperatures, Army rolled homogeneous armor in a hardness range of 255 to 302 Bhn be approved for use.

SUBMITTED:

W. K. Resnick
W. K. RESNICK
Capt, ARMOR
Proof Officer

REVIEWED:

W. C. Piess
W. C. PLESS
Chief, Armor Branch

C. D. Montgomery
W. A. GROSS, JR
Chief, Automotive Division

APPROVED:

H. A. Noble
H. A. NOBLE
Assistant Deputy Director
for Engineering Testing
Development and Proof Services

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REFERENCES

**Armor Test Report No. AD-1255 and 56th Report on Project TT1-5,
Titled: Armor Protection Against Land Mines.**

APPENDICES

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APPENDIX A

Letter Directive

ARMOR BRANCH

ARMOR AND AMMUNITION EFFECTIVENESS DIVISION

DIVISION TEST PLAN

DATE: 5 Mar 1957
PLAN NO.: AE-11

PROJECT TITLE:

Armor Protection Against Land Mines

PROJECT ENGINEER: ?

PROJECT NO.: FT1-5B/64

OBJECT OF TEST: To obtain information on relative performance of 1" armor of several hardness levels in resisting land mine attack at ambient and sub-zero temperatures.

BACKGROUND: Some testing has been done to obtain the information indicated above. However, variations in test methods & results precluded arriving at definite conclusions. The proposed tests will be performed in a more systematic manner in an effort to obtain the desired information.

ITEMS UNDER TEST:

Six plates 5"x7"x1" of each of the following rolled homogeneous armor:

STS armor - BHN 255
Army Armor - BHN 302

Army Armor BHN 255
Army Armor BHN 362

APPROX. DATES OF TEST: Material not expected
for several months

NO. OF ROUNDS: 25-30

OUTLINE OF PROGRAM:

1. Place crack starter (welded block 2"x2"x3") in center of each plate
2. Magnaflux welds
3. Test 3 of each type plate at ambient temperature and 3 at - 100°F
 - a. Plates will be mounted flat on 2 steel members 12" above ground
 - b. A heavy frame with beveled inner edge will be placed atop the plate and on top of the frame will be placed a heavy hold down plate.
 - c. Mine will be placed 17" below the center of the plate, will be covered with 3" of loosely packed soil and will be statically detonated.
 - d. Amount of plate deformation and cracking, if any, will be recorded.
 - e. Weights of charges will be determined from previous firings and, if necessary, will be adjusted during the course of the test.
4. Formal report will be prepared.

APPROVED: /s/ HERBERT L. ROSENBERG

Chief, Armor & Ammunition Effectiveness
Division

ORDMC-EM.1 1st Ind
OTAC 476/APG (19 Nov 56)
ORDEG-LP-TE APG 400.112/5377 (1956)
SUBJECT: Armor Protection Against Land Mines

Hq, Ordnance Tank-Automotive Command, Res & Dev Div, Detroit Arsenal
Center Line, Michigan FEB 18 1957

TO: Commanding General, Aberdeen Proving Ground, Maryland
ATTN: ORDEG-LP-TE, Mr. H. M. Greener Jr.

1. The tests outlined in basic letter are hereby authorized.
2. Funds in the amount of \$10,000 have been issued and PERSD 70405330-11-80022 has been forwarded to Aberdeen Proving Ground to cover the test required. These funds are in the approved project area.
3. This Command will purchase the necessary 24 armor plates (1'x5'x7').
4. Distribution of memorandum and final reports should be in accordance with attached distribution lists.

FOR THE COMMANDER:


C. S. RASMUSSEN
Assistant

(03) Incls
w/d Incl 1
Added 2 Incls
2. Memo Rpt Distribution List
3. Final Rpt Distribution List

**ORDNANCE CORPS
ABERDEEN PROVING GROUND**

**MARYLAND
DEVELOPMENT AND PROOF SERVICES**

Mr. B. B. Cressman Jr. / rvp/33215

IN REPLY REFER TO
ORDEG-DP-TE

Copy 100-44/5377 (148)

SUBJECT: Armor Protection Against Land Mines

**TO: Commanding General
Ordnance Tank-Automotive Command
Detroit Arsenal
Center Line, Michigan**

ATTENTION: ORDMC-RM.1

- REFERENCES:**
- a. Letter 13 Sep 1955, file APG CMH 476/13, 00/53 20491, Det Ars 476/APG (13 Sep 55) CMH, Subject: First Memorandum Report on Armor Protection Against Land Mines - Expansion of Project TT1-5B (U), with 1st, 2d and 3d indorsements.
 - b. Letter 14 July 1955, file APG 400.112/3-248, Det Ars 400.112/APG (14 July 55), Subject: Winter Armor Ballistic Test Program Being Planned for Fort Churchill, Canada 1955-56 (U), with 1st, 2d and 3d indorsements.
 - c. Teletype Detroit Arsenal 26 April 1955 TT68385.
 - d. Aberdeen Proving Ground Firing Record No. AR-21392.

1. References a. and d. contain results of tests designed to determine the resistance to cracking and deformation of 1" homogeneous armor (STS-Navy type and Army armor) against land mine attack at ambient and sub-zero temperatures. A review of the results reported therein indicates the need for considerable additional firing to more definitely establish the relative performance of the two types of material and the optimum hardness of material for tank floor plates. In short, so many variables in test procedures were employed in an effort to arrive at the most reproducible test method, and results were consequently of such a variable nature, that definite conclusions cannot be drawn from these data.

2. Through trial and error it has been established that the most satisfactory method of mounting the items for test is as shown in sketch 1, inclosure 1, and described below:

a. A 2" square x 3" high steel block is placed centrally on the top surface of the 5' x 7' test plate and is fillet welded (1/4" austenitic electrode) by a single pass around the perimeter of the block.

C 1. 9. 3

RECEIVED NOV 23 1955
DETROIT ARSENAL
(19 Nov 55)

ORDEG-DP-TE

SUBJECT: Armor Protection Against Land Mines

b. The test plate is set in an horizontal position with its two 7' sides resting on and extending 2" over 1' x 1' x 7' steel supports placed on the ground. Distance between the two steel supports is 56 inches.

c. A steel frame 8" thick, to provide for maximum plate deformation, and an 8-ton hold-down plate are placed atop the test plate.

d. The mine is emplaced beneath the center of the test plate at a distance of 17" from top of mine to the bottom surface of the plate, and the mine is covered with three inches of loose soil and is statically detonated.

3. Much of the current testing to determine the mine explosive weight required to defeat Army armor of specification hardness and of various thicknesses from 1/4" through 1-1/2" has been carried out using the method just described and results, for the most part, are consistent for given explosive weight/armor thickness combinations.

4. It is recommended that tests previously carried out in an effort to compare STS and Army armor and to compare different hardnesses of Army armor be repeated using the improved technique described above and employing a mine explosive weight to be determined from the tests referred to in paragraph 3. It is the opinion that at least 3, and preferably 5, trials should be conducted for each combination of plate type/plate hardness/and test temperature. For such a program the following material would be required:

<u>Plate Size</u>	<u>Type Armor</u>	<u>Hardness</u>	<u>Test Temperature</u>	<u>Number of Plates Minimum</u>	<u>Plates Desired</u>
1" x 5' x 7'	STS	255	Ambient	3	5
1" x 5' x 7'	STS	255	Sub-zero	3	5
1" x 5' x 7'	Army RH	255	Ambient	3	5
1" x 5' x 7'	Army RH	255	Sub-zero	3	5
1" x 5' x 7'	Army RH	302	Ambient	3	5
1" x 5' x 7'	Army RH	302	Sub-zero	3	5
1" x 5' x 7'	Army RH	362	Ambient	3	5
1" x 5' x 7'	Army RH	362	Sub-zero	3	5

ORDEG-DF-78

SUBJECT: Armor Protection Against Land Mines

5. It is estimated that the cost of testing the above plates would be \$10,000 for the minimum sample size and \$16,000 for the desired sample size. Comments at an early date would be appreciated.



T. F. COLLERAN
Director

1 Incl
1. Sketch

98

BSpire/pw/24-106

ORDMC-RM.1

17 February 1958

SUBJECT: Test Directive for Mine Test Program
for 1" Rolled Armor

TO: Commanding General
Aberdeen Proving Ground
Aberdeen, Maryland
ATTENTION: Mr. W. C. Fless

REFERENCE: a. PASD 70405330-11-80022 dtd 30 Jan 57
b. Ltr File No. AFG 400.112/5377 dtd 19 Nov 56

1. Twenty-four (24) plates of 1" rolled armor plate of various hardness are to be shipped to Aberdeen Proving Ground from Lukens Steel Company by 1 March 1958.

2. The funding for testing the armor plates is covered by reference "a".

3. The original test program, reference "b", is to be revised slightly as noted below:

a. Type of mine: 20# (comp B).

b. Crack Starter: Welds should be ground and then checked for cracks.

c. Method of Testing: See attached sketch for Plates 1 through 4. Plates 5 and 6 are to be used as check plates.

4. This office desires to be notified in advance of scheduled firings to permit attendance by interested personnel.

FOR THE COMMANDER:

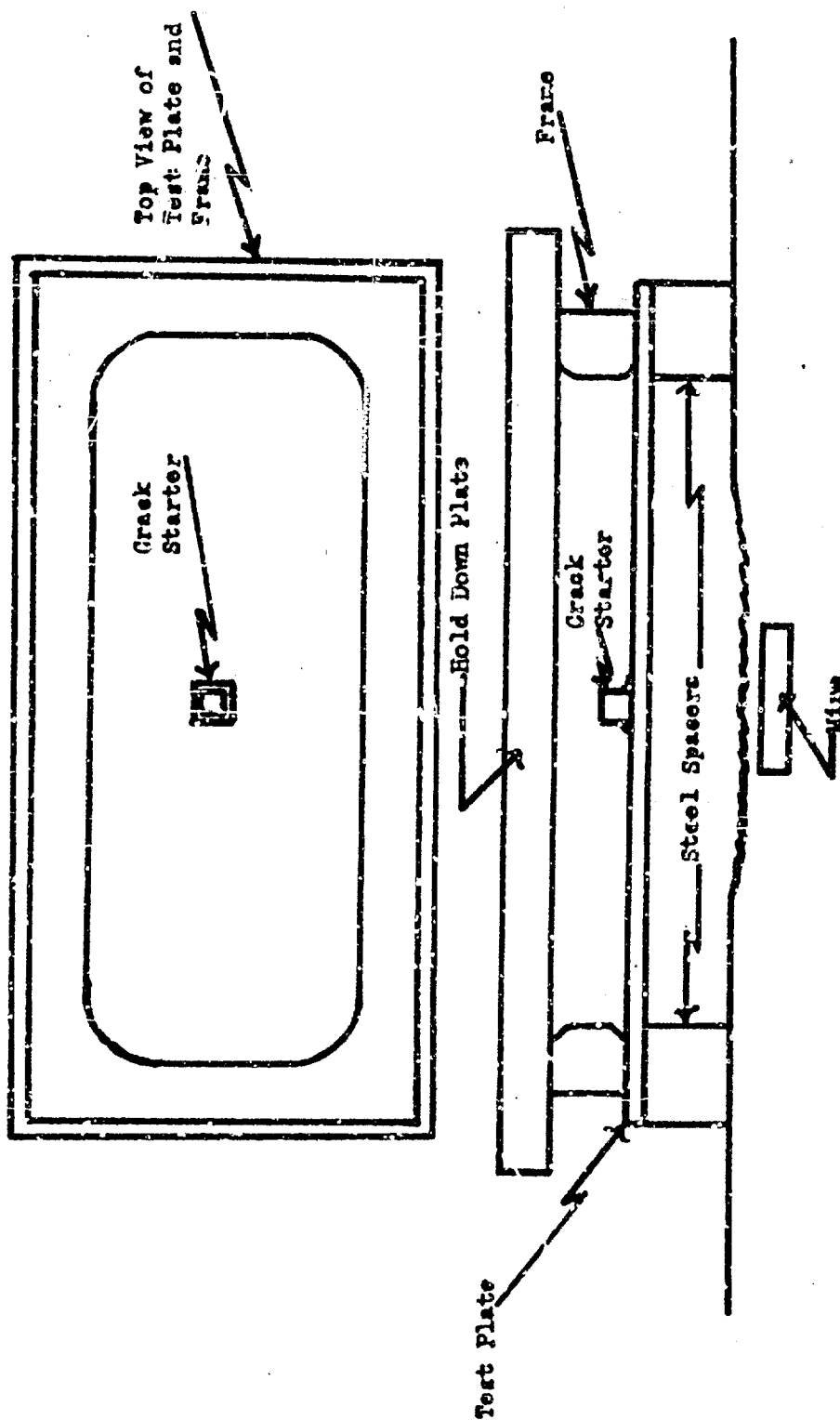
1 Incl
Sketch of Method
of Testing (in dupe)

W. D. ENGLAND
Chief, Materials Branch

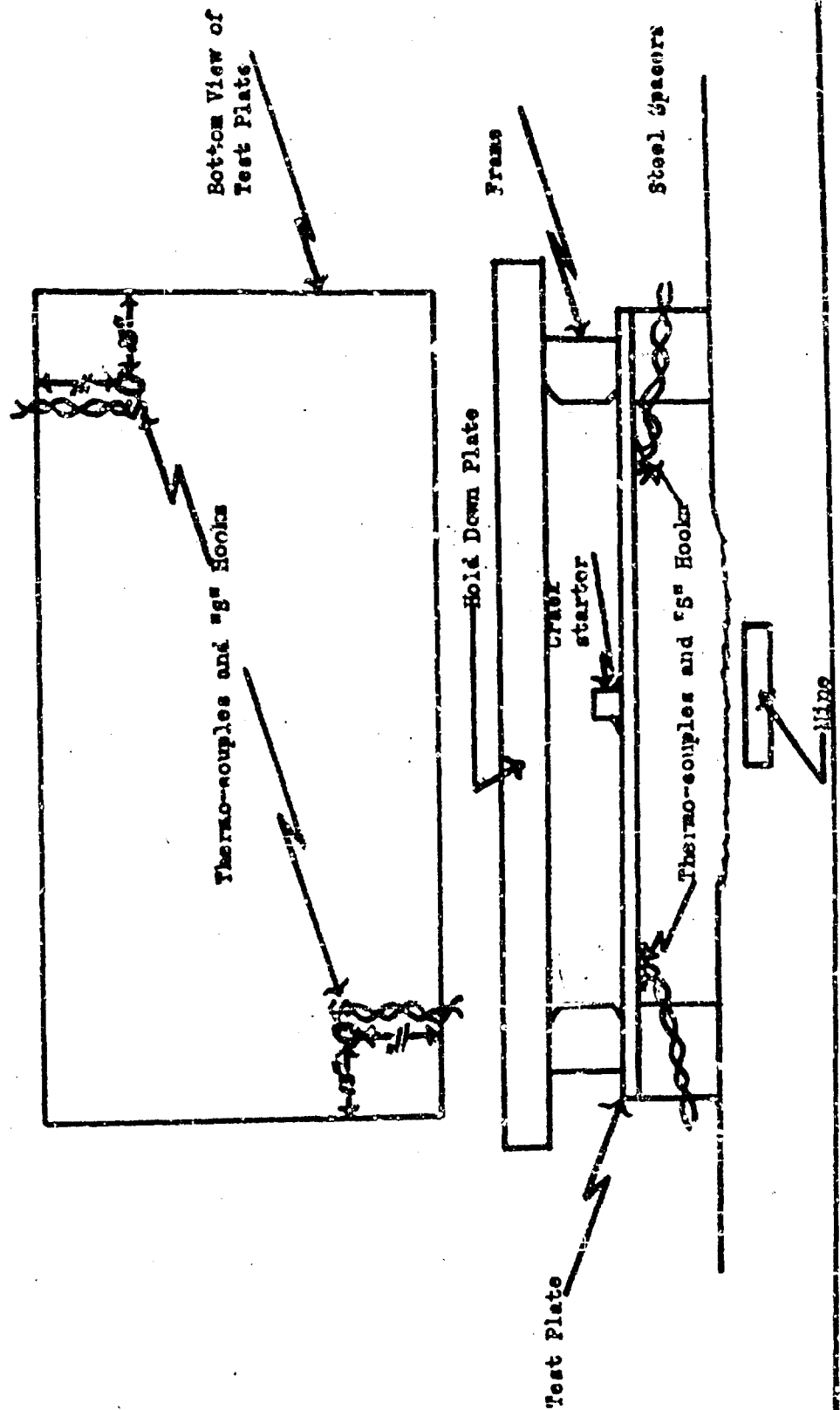
APPENDIX E

Sketches of Test Setup

Sketch 1



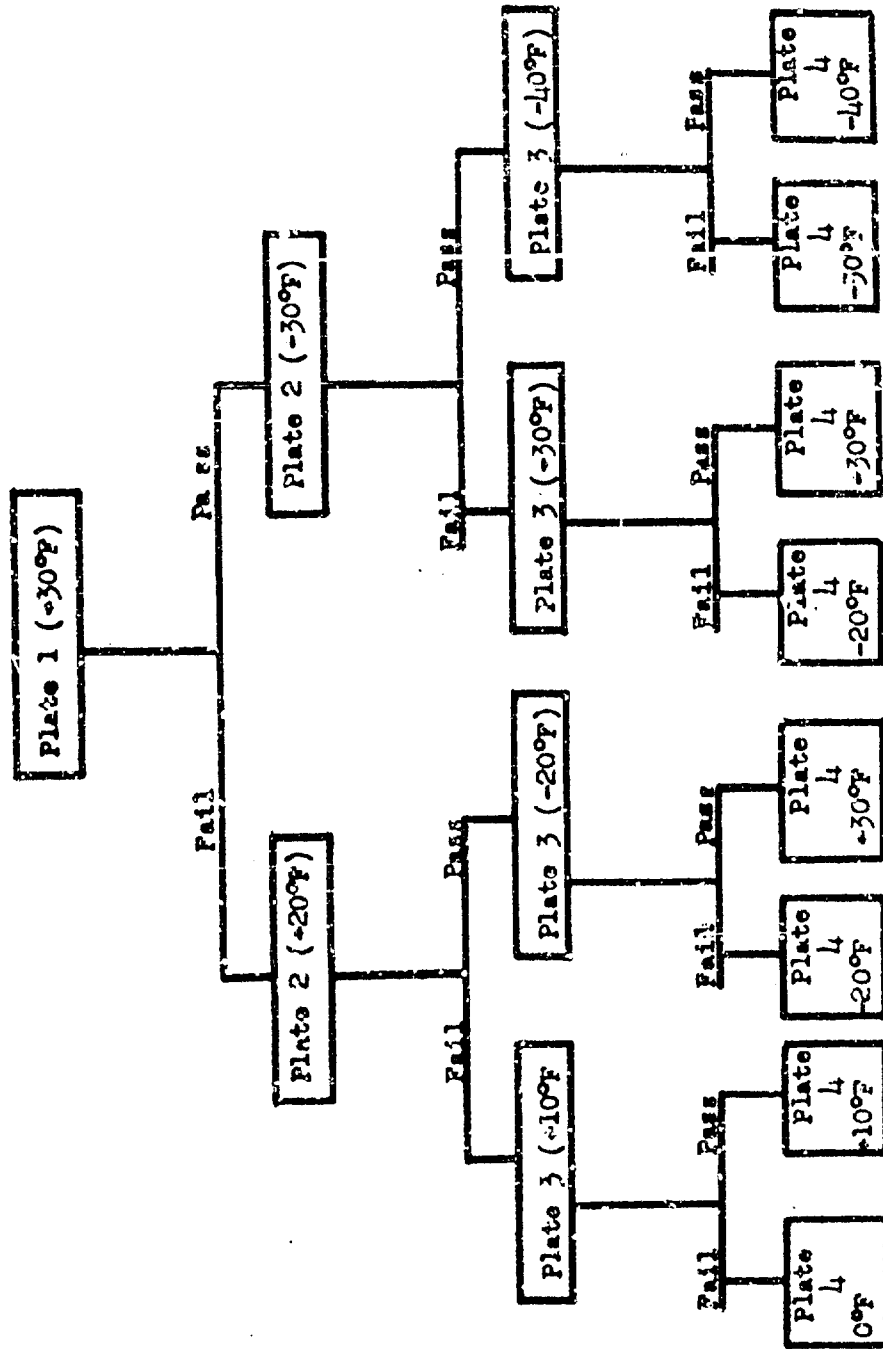
Sketch 2



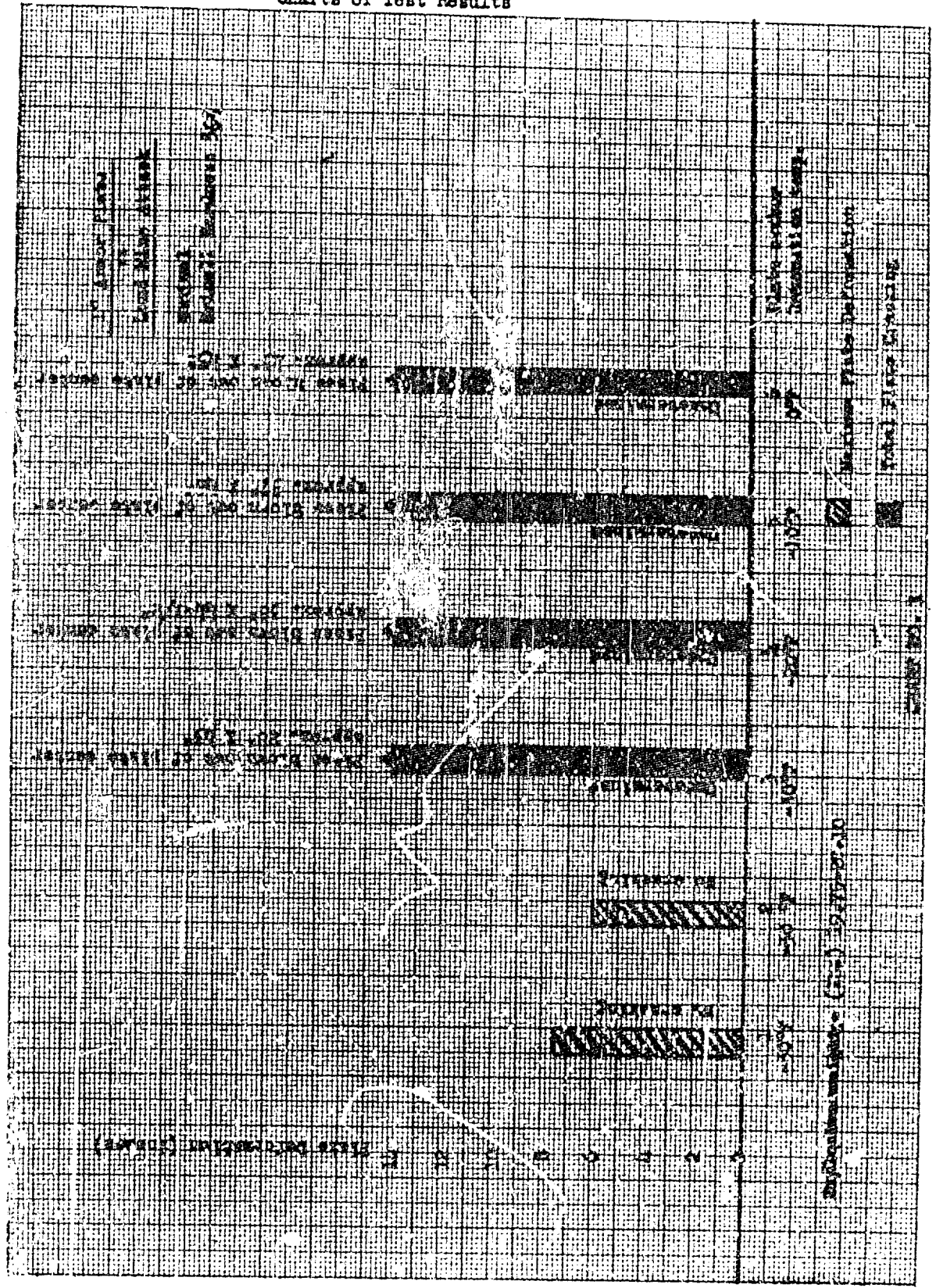
APPENDIX C

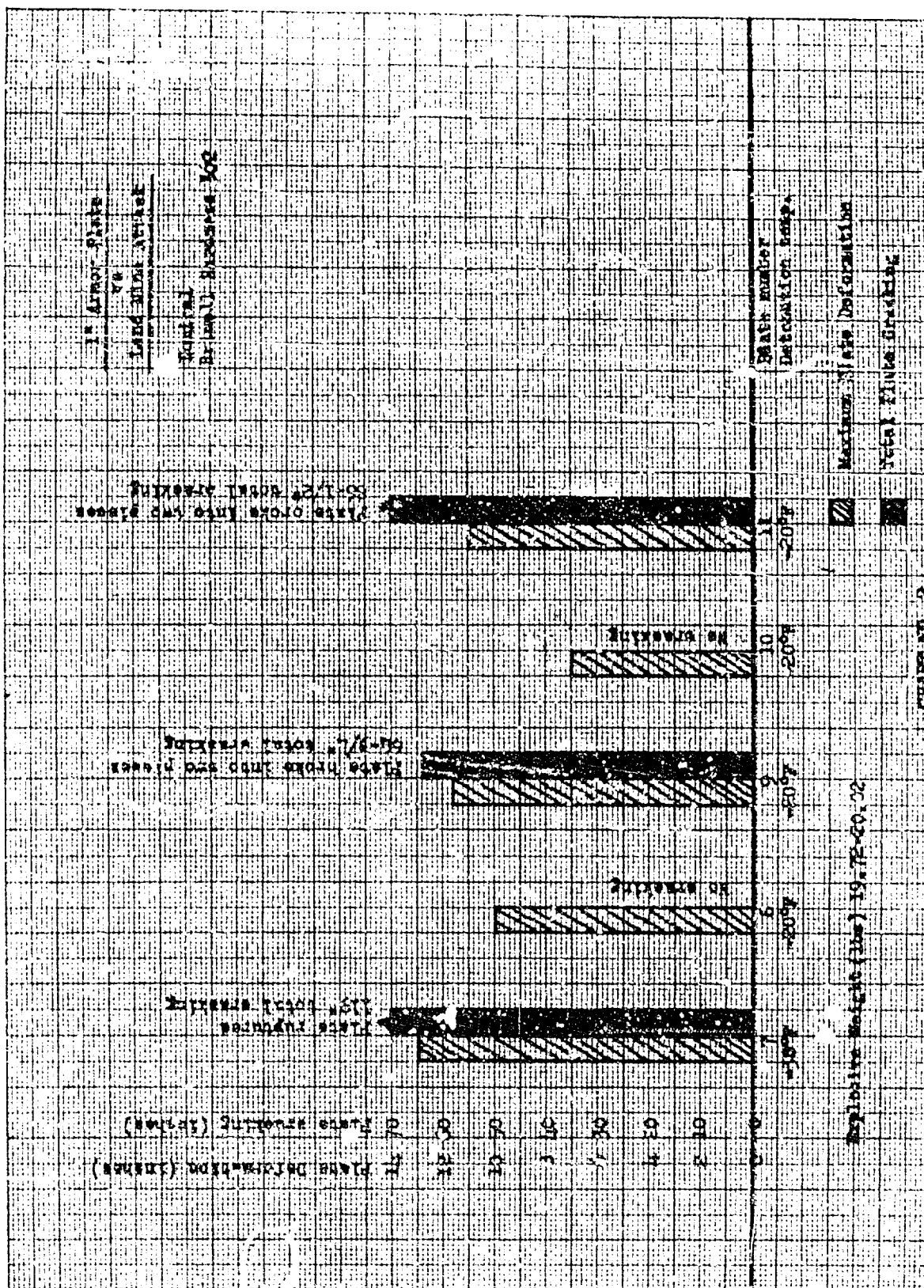
Program for Testing Armor Plate

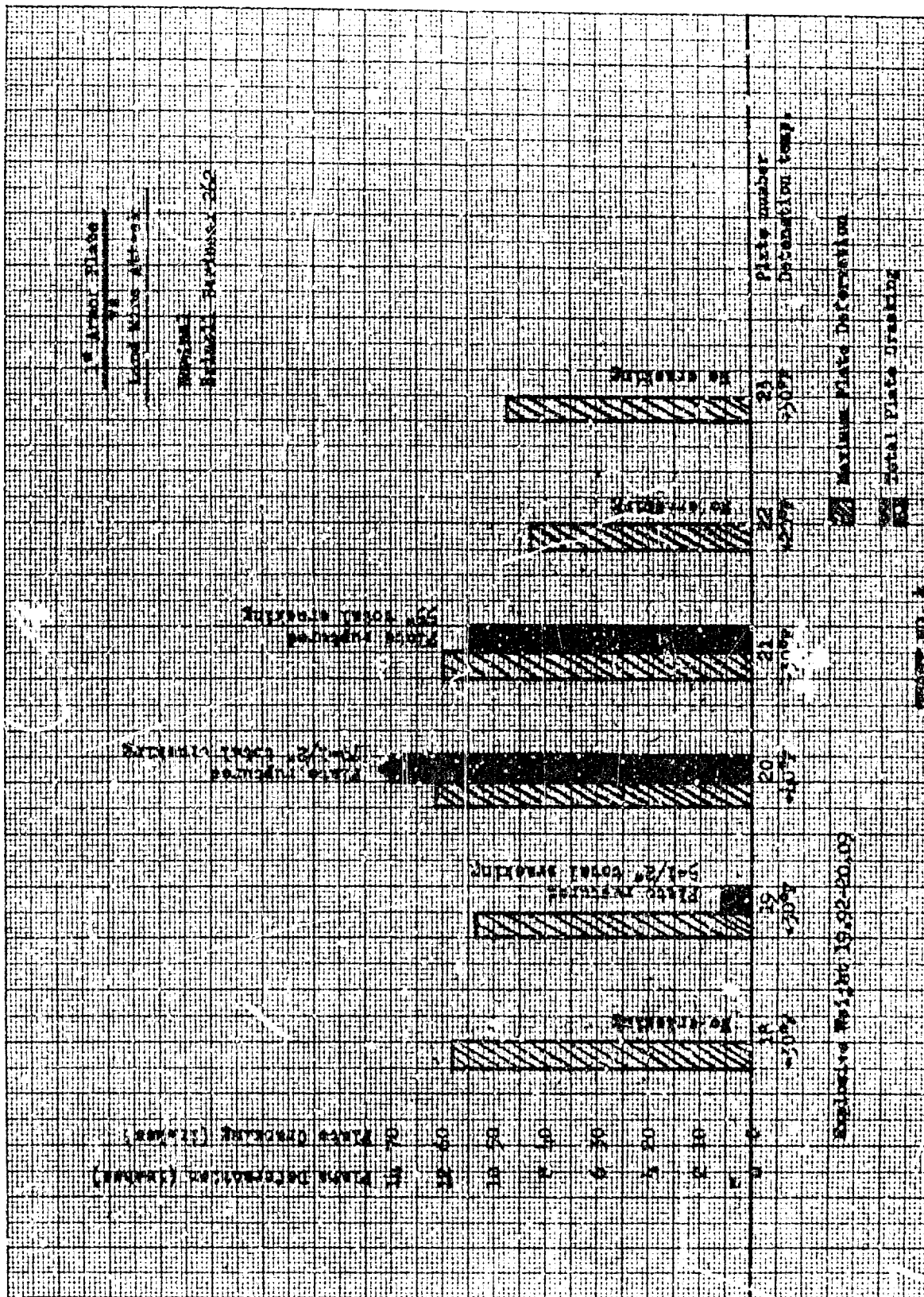
PROGRAM FOR TESTING ARMOR PLATE MATERIAL WITH MINES



APPENDIX D
Charts of Test Results







APPENDIX E

Physical Test Laboratory Report

ENGINEERING LABORATORIES PHYSICAL TEST LABORATORY REPORT

ORDBG-DP-LP

EXAMINATION OF:

Twenty-three Samples of
1" Wrought Armor.

OBJECT OF EXAMINATION:

To obtain Brinell Hardness
and Charpy Impact Data on the
plates.

EXAMINATION PROCEDURE:

1. 4" square plates were
sawed from flame cut samples
and supplied to the laboratory
for determination of the major
working direction.

2. The test samples were macroetched for one hour in 50% HCL. The
major working direction was indicated and the samples were returned to
the machine shop for machining standard Charpy "V" notch specimens, one
specimen from each sample.

3. Charpy specimens were cooled to -40° F for 30 minutes, and broken
on the impact testing machine. Fracture ratings were made on the specimen
fracture surfaces.

4. Brinell hardness readings were taken on the broken Charpy specimens.

RESULTS:

Tabulated results follow:

<u>Spec. No.</u>	<u>Energy, ft-lbs.</u>	<u>Fracture, % Shear</u>	<u>BHN*</u>	<u>Spec. Charpy Energy, ft-lbs.</u>
1	22.5	25	352-	16.7
2	17	25	363	15.0
3	15.5	25	352-	16.7
4	14.5	25	363	15.0
5	16.5	25	352-	16.7
6	14	25	363	15.0
7	36.5	100	311+	25.4
8	40	100	311+	25.4

<u>Spec. No.</u>	<u>Energy, ft-lbs.</u>	<u>Fracture, % Shear</u>	<u>PHN</u>	<u>Spec. Charpy Energy, ft-lbs.</u>
9	39.5	100	302	28.0
10	46	100	277	38.4
11	38.5	100	311	25.4
12	64.5	85	217	53.5 **
13	53.5	100	217	53.5 **
14	54.5	100	229	48.0 **
15	60.5	100	229	48.0 **
16	58	100	223	50.7 **
17	58.5	100	223	50.7 **
18	64.5	100	241	43.0 **
19	78.5	100	255	37.0 **
20	76	100	248	40.0 **
21	80	100	241	43.0 **
22	74.5	100	241	43.0 **
23	84	100	241	43.0 **

* Specified BHN for 1" plate is 331-375.

** Hardness values are outside range given for plate up to 4", so Charpy values are applicable to plate 4"-12" only.

SUMMARY OF RESULTS:

1. Plates 1-6 met the specification hardness requirement. Plates 1-2 and 7-23 met the specification impact requirement. Only plates 1 and 2 met both hardness and impact requirements.

SUBMITTED:

R. L. Huddleston
R. L. HUDDLESTON
Chief,
Radiographic & Metallurgical Section

APPROVED:

J. M. McKinley
J. M. McKINLEY
Chief,
Physical Test Laboratory

APPENDIX F

Manufacturer's Chemical and Physical Test Reports

Form ORDNX-1
21 Dec 49 3983

ARMOR DATA CHECK SHEET
SIP-12

ORDNANCE DEPARTMENT
DETROIT ARSENAL

MFG. RECORD NO.		PRIMARY CONTRACTOR		FIRING RECORD NO.	
MFG. LUKENS STEEL COMPANY		PHILA. ORD. DISTRICT		FIRING DATE	
ADDRESS COATESVILLE, PA.		128 N. BROAD ST.		SPECIFICATION MIL-A-12560	
MFG. DATE 10/27/57		PHILADELPHIA 2, PA.		REVISION AMENDMENT	
SHIPPED TO ABERDEEN PROV. ORDS.		CONTRACT		TYPE ARMOR: HOMO X FH	
SHIPPED VIA: FRT EXP TRK X		DA-36-034-ORD-2525RD		CAST ROLLED FORGED	
PURPOSE: ACC QUAL DEV X		FILE# 2525 R.D.		FURNACE: OH X ELECT.	
SAMPLE: PRIMARY RETEST CASTING		ORDNANCE DISTRICT (OR ARSENAL)		BASIC ACID	
REPRESENTS: 9,000 LBS.		PHILA. ORD. DISTRICT		STEEL SOURCE LUKENS STEEL CO	
CASTING NO.				MATERIAL FOR USE ON RESEARCH & DEVELOPMENT	

CHEMICAL COMPOSITION								STEEL MILL FRACTURE DATA			
C	Mn	Si	S	P	Cr	Ni	Mo	LOCATION	1ST INGOT	MID. INGOT	END INGOT
1 26	1.61	24	022	016	08	21	47	TOP	A-	A-	A-
2								MIDDLE	A-	A-	A-
3								BOTTOM	A-	A-	A-

HEAT TREATMENT									
CARBURIZE		HOMOGENIZE		NORMALIZE		HARDEN		DRAW	
TEMP	TIME	TEMP	TIME AT TEMP	TEMP	TIME AT TEMP	TEMP	TIME AT TEMP	TEMP	TIME AT TEMP
1						1650°F.	2 HRS.	950°F.	2 HRS.
2									
3									

HEAT NO.	INGOT	SLAB	PLATE NO.	THICK	SIZE	REQ BHN	ACTUAL BHN	HEAT TREATED FRACTURE
1 1122104						331/375		
2						364		
3								

PHYSICAL PROPERTIES					RADIOGRAPHIC INSPECTION	
CHARPY		BHN		IMPACTS		
TEMP	FT LBS			ELONG 2"	RA %	STANDARD
1 -40°F.		352 AVG	19.5 AVG.			
2		352/352	17.5-18.5			
3		341 AVG	17.5 AVG.			

REMARKS: 3 PLATES SHIPPED ON MELT LL22104 1-1 SIZE-84 X 60 X 1" BHN RANGE 351/375
 1/3 PLATES SHIPPED ON MELT LL22104 2-3 SIZE-84 X 60 X 1" BHN RANGE 364/364

H.A. GRIFFIN *H.A. Griffin*
 MFG. ENGR. PLANT, LUKENS STEEL CO.

BALLISTIC TEST RECORD							
TEST	PROJECTILE	OBL.	THKS.	REQ. VEL.	ACT. VEL.	RESULT	REMARKS
1							
2							
3							

PROOF FACILITY SIGNATURES

ARMOR DATA CHECK SHEET
SIP-12ORDNANCE DEPARTMENT
DETROIT ARSENAL

MFG. RECORD NO.		PRIMARY CONTRACTOR		FIRING RECORD NO.	
MFG. LUKENS STEEL COMPANY		PHILA. ORD. DISTRICT		FIRING DATE	
ADDRESS COATESVILLE, PA.		128 N. BROAD ST.		SPECIFICATION MJL-A-12560	
MFG. DATE 9/27/57		PHILADELPHIA 2, PA.		REVISION AMENDMENT	
SHIPPED TO ABERDEEN PROV. GRDS.		CONTRACT		TYPE ARMOR: CAST	
SHIPPED VIA: FRT EXP TRK X		DA-36-034-ORD-2525RD		HOMO X ROLLED	
PURPOSE: ACC QUAL DEV X		FILE# 2525 R.D.		FM FORGED	
SAMPLE: PRIMARY RETEST CASTING		ORDNANCE DISTRICT (DET. ARSENAL)		FURNACE: OM X ELECT. ACID	
REPRESENTS: 9,000 LBS.		PHILA. ORD. DISTRICT		STEEL SOURCE LUKENS STEEL CO.	
CASTING NO.				MATERIAL FOR USE ON RESEARCH & DEVELOPMENT	

CHEMICAL COMPOSITION								STEEL MILL FRACTURE DATA			
C	Mn	Si	S	P	Cr	Ni	Mo	LOCATION	1ST INGOT	MID. INGOT	LAST INGOT
26	1.51	24	0.22	0.16	0.8	21	47	TOP	A-	A-	A-
2								MIDDLE	A-	A-	A-
3								BOTTOM	A-	A-	A-

HEAT TREATMENT									
CARBURIZE		HOMOGENIZE		NORMALIZE		HARDEN		DRAW	
TEMP	TIME	TEMP	TIME AT TEMP	TEMP	TIME AT TEMP	TEMP	TIME AT TEMP	TEMP	TIME AT TEMP
1						1650°F.	2 HRS.	1050°F.	2 HRS.
2									
3									

HEAT NO.	INGOT	SLAB	PLATE NO.	THICK	SIZE	REQ BHN	ACTUAL BHN	HEAT TREATED FRACTURE
1 LL22104						293/321		
2						302		
3								

PHYSICAL PROPERTIES						RADIOGRAPHIC INSPECTION	
CHARPY		BHN	IMPACTS			STANDARD	PASSED OR FAILED
TEMP	FT LBS		ELON 5 2"	HA 5			
1	-40°F.	302	59.0-35.0				
2	Drawn	302	59.5-36.0				
3		302	40.0-40.0				

REMARKS: 1 PLATES SHIPPED ON MELT LL22104 1-2 SIZE-84 X 60 X 1" BHN RANGE 321/321
2 PLATES SHIPPED ON MELT LL22104 1-3 SIZE-84 X 60 X 1" BHN RANGE 293/321
H.A. GRUBB H.A. Grubb and Treat
DET. ENGR. PLANT, LUKENS STEEL CO.

BALLISTIC TEST RECORD							
TEST	PROJECTILE	WGT.	THRS.	REQ. VEL.	ACT. VEL.	RESULT	REMARKS
1							
2							
3							

PROOF FACILITY SIGNATURES

Form ORDN-1 21 Dec 49 3983										ARMOR DATA CHECK SHEET SIP-12										ORDNANCE DEPARTMENT DETROIT ARSENAL														
MFG. RECORD NO.										PRIMARY CONTRACTOR PHILA. ORD. DISTRICT 128 N. BROAD ST. PHILADELPHIA 2, PA. CONTRACT DA-36-034-ORD-2525RD FILE# 2525 R.D. ORDNANCE DISTRICT (OR ARSENAL) PHILA. ORD. DISTRICT										FIRING RECORD NO.														
MFG. LUKENS STEEL COMPANY																				FIRING DATE														
ADDRESS COATESVILLE, PA.																				SPECIFICATION MIL-A-12560														
MFG. DATE 10/27/57																				REVISION AMENDMENT														
SHIPPED TO ABERDEEN PROV. GRDS.																				TYPE ARMOR: HOMO X FH														
SHIPPED VIA: FRT EXP TRK X																				CAST ROLLED FORGED														
PURPOSE: ACC GUAL DEV X										FURNACE: ON X ELECT.																								
SAMPLE: PRIMARY RETEST CASTING										BASIC ACID																								
REPRESENTS: 9,000 LBS.										STEEL SOURCE LUKENS STEEL CO.																								
CASTING NO.										MATERIAL FOR USE ON RESEARCH & DEVELOPMENT																								
CHEMICAL COMPOSITION															STEEL MILL FRACTURE DATA																			
C	Mn	Si	S	P	Cr	Ni	Mo								LOCATION	1ST INGOT	MID. INGOT	LAST INGOT																
1 26	1.61	24	022	016	08	21	47								TOP	A-	A-	A-																
2															MIDDLE	A-	A-	A-																
3															BOTTOM	A-	A-	A-																
HEAT TREATMENT																																		
CARBURIZE					HOMOGENIZE					NORMALIZE					HARDEN					DRAW														
TEMP TIME					TEMP TIME AT TEMP					TEMP TIME AT TEMP					TEMP TIME AT TEMP					TEMP TIME AT TEMP														
1										1650°F. 2 HRS.					1175°F. 2 HRS.					WATER														
2																																		
HEAT NO.					INGOT		SLAB		PLATE NO.		THICK		SIZE		REQ BHN		ACTUAL BHN		HEAT TREATED FRACTURE															
1 L1 22104															241/269																			
2															241																			
3																																		
PHYSICAL PROPERTIES															RADIOGRAPHIC INSPECTION																			
CHARPY										BHN					IMPACTS																			
TEMP FT LBS										XXXXXXXXXXXXXX					ELONG % 2"					RA %					STAIN XRS					PASSED OR FAILED				
1 -40°F.										241					60.0-59.5																			
2										241					60.0-62.0																			
3										241					62.0-59.0																			
REMARKS 3 PLATES SHIPPED ON MELT LL22104 2-2 SIZE 84 X 60 X 1" BHN RANGE 255/255 3 PLATES SHIPPED ON MELT LL22104 2-1 SIZE 84 X 60 X 1" BHN RANGE 241/255 <div style="text-align: right;"> H.A. GRUBB <i>H.A. Grubb</i> MET. ENGR. PLANT, LUKENS STEEL CO. </div>																																		
BALLISTIC TEST RECORD																																		
TEST	PROJECTILE					OBL.		TKS.		REQD. VEL.		ACT. VEL.		RESULT		REMARKS																		
1																																		
2																																		
3																																		
PROOF FACILITY SIGNATURES																																		

PHILADELPHIA ORD. DISTRICT
128 N. BROAD ST.
PHILADELPHIA 2, PA.

LUKENS STEEL COMPANY
COATESVILLE, PA.

TEST REPORT
AFFI

FORM NO. 221

PS

DATE
APR. 17, 1958

LUKENS OFFICE NO.
459-1

SPECIFICATIONS
MIL-8-20154A

CUSTOMER ORDER NO.

DA-36-034-ORD-2525RD

TO : ABERDEEN PROVING GRDS.

: ABERDEEN, MD.

: ATT: COMMANDING GENERAL

: ORDBG-DT-TT/MR. W. C. PLESS

REPORT OF CHEMICAL AND PHYSICAL TESTS OF

S. T. STEEL

CAR NO.

MILL ORDER NO.

8251-VR-19312-1

HOMOGENEITY TESTS BENDING TESTS

O.K.

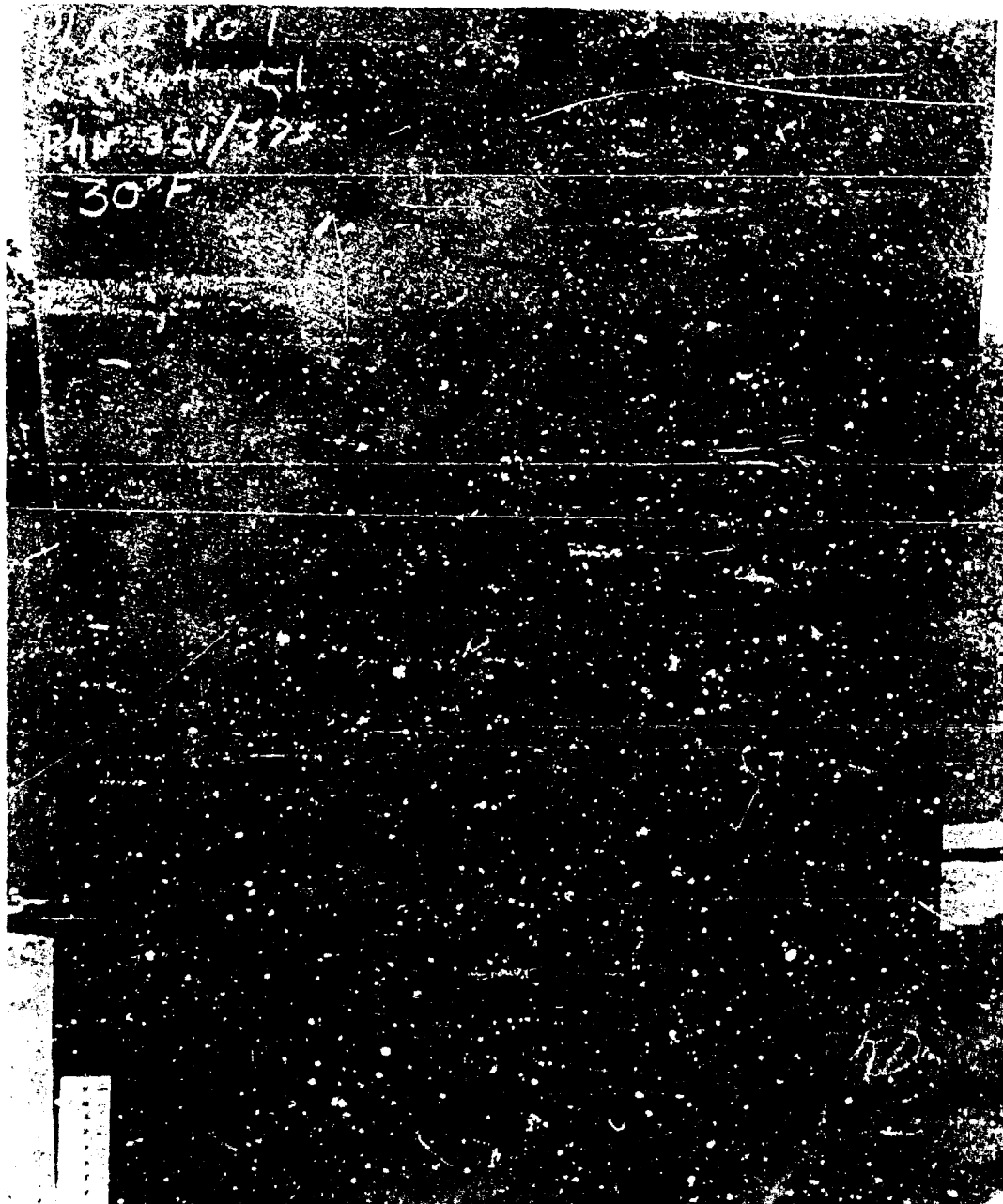
MELT NO.	SLAB NO.	CHEMICAL ANALYSIS										YIELD P.S.I.	TENSILE P.S.I.	% ELONGATION RED. OF AREA	BHN	SIZE OF PLATE	
		C	MN	P	S	CU	SI	NI	CR	MO							
19026	38	26	22	014	026		25	3.22	1.30			104000 102000	122500 121700	23 24	66.0 66.7	262 262	6-84 X 60 X 1"
262																	
F-4																	
PLATES AND TESTS QUENCHED AND TEMPERED.																	
ABOVE PLATES HAVE MET BALLISTIC REQUIREMENT OF SPECIFICATION.																	
THE ABOVE TESTS WITNESSED BY USN INSPECTOR.																	
APR 17 1958																	

I HEREBY CERTIFY THAT THE ABOVE TESTS ARE CORRECT TO THE BEST OF MY KNOWLEDGE AND BELIEF.

LUKENS STEEL COMPANY

ASS'T ENGR OF TESTS

CONFIDENTIAL



B31891: Plate No. 1, HEAT No. LL-22104 1-1, Bhn Range 351/375. Front View. Detonated at -30°F.

G-1

CONFIDENTIAL

CONFIDENTIAL

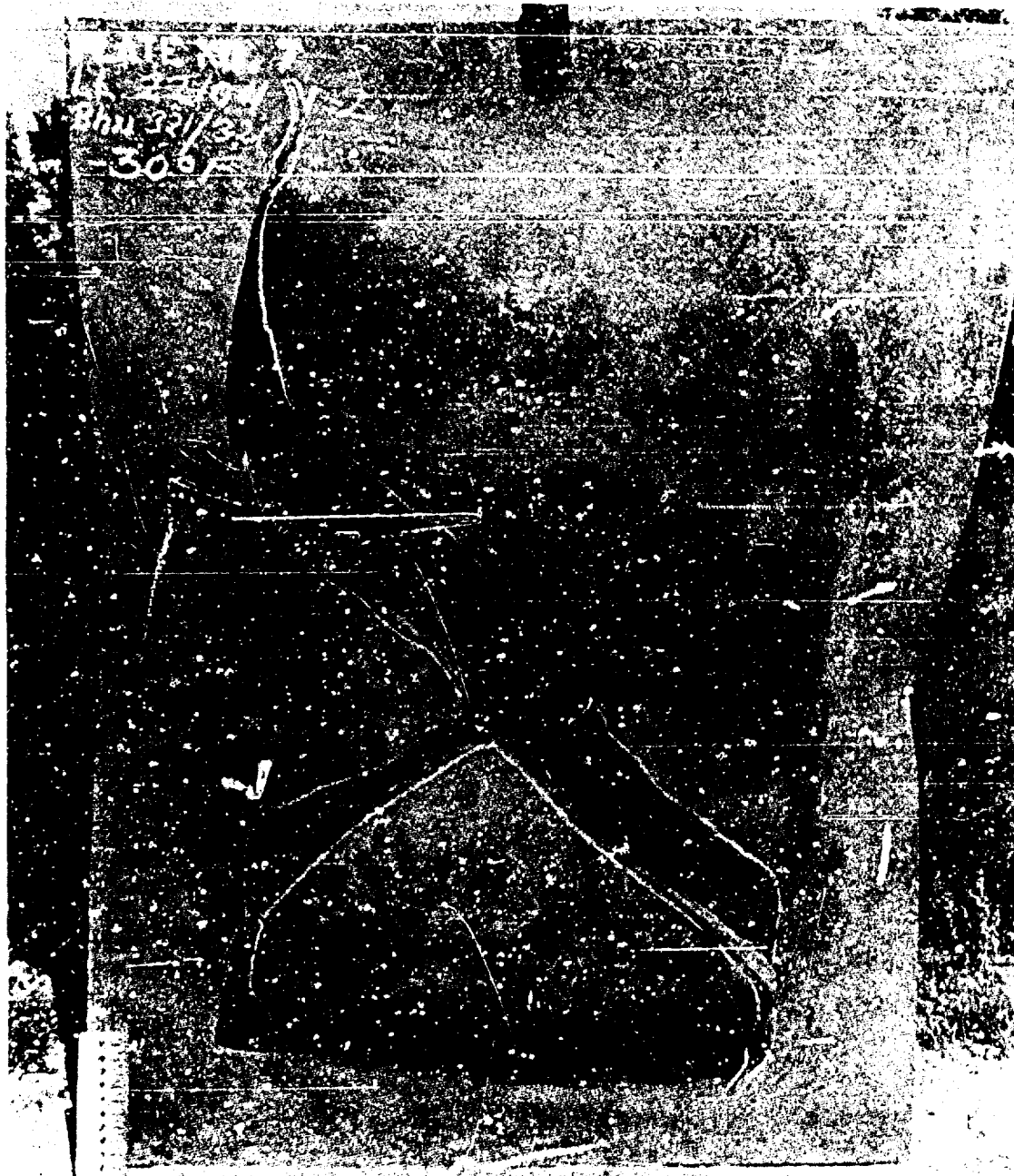


B31890: Plate No. 1, HEAT No. IL-22104 1-1, Ehn Range 351/375. Rear View. Detonated at -30°F.

G-2

CONFIDENTIAL

CONFIDENTIAL



131892: Plate No. 7, HEAT No. LL-22104 1-2, Bhn Range 321/321. Front View. Detonated at -30°F.

G-3

CONFIDENTIAL

CONFIDENTIAL



B31893: Plate No. 7, HEAT No. 22104 1-2, Elm Range 321/321. Rear View. Detonated at -30°F.

G-4

CONFIDENTIAL

CONFIDENTIAL



B31894: Plate No. 8, HEAT No. LL-22104 1-2, Bhn Range 321/321. Rear View. Detonated at -20°F.

G-5

CONFIDENTIAL

CONFIDENTIAL



B31895: Plate No. 8, HEAT No. 22104 1-2, Bhn Range 321/321. Front View. Detonated at -20°F.

CONFIDENTIAL

CONFIDENTIAL



B31896: Plate No. 14, HEAT No. LL-22104 2-2, Bhn Range 255/255. Rear View. Detonated at -20°F.

G-7

CONFIDENTIAL

CONFIDENTIAL



B31897: Plate No. 14, HEAT No. LL-22104 2-2, Bin Range 255/255. Front View. Detonated at -20°F.

G-0

CONFIDENTIAL

CONFIDENTIAL



B31898: Plate No. 15, HEAT No. LL-22104 2-1, Ehn Range 241/255. Front View. Detonated at -30°F.

6-9
CONFIDENTIAL

CONFIDENTIAL



B31899: Plate No. 19, HEAT No. 19026 3-P, Bhn Range 262. Front View.
Detonated at -30°F.

CONFIDENTIAL

CONFIDENTIAL



B31900. Plate No. 19, HEAT No. 19026 3-B, Bhn Range 262. Rear View.
Detonated at -30°F.

G-11

CONFIDENTIAL

CONFIDENTIAL



B31001: Plate No. 21, HEAT No. 19026 3-B, Bhn Range 262. Rear View.
Detonated at -30°F.

C-12

CONFIDENTIAL

CONFIDENTIAL



B31902: Plate No. 21, HEAT No. 19026 3-B, Rhn Range 262. Front View.
Detonated at -30°F.

G-13

CONFIDENTIAL

CONFIDENTIAL



B31903: Plate No. 16, HEAT No. LL-22104 2-1, Bhn Range 241/255. Front View. Detonated at -20°F.

G-14

CONFIDENTIAL

CONFIDENTIAL



B31904: Plate No. 16, HEAT No. LL-22104 2-1, Bhn Range 211/255. Rear View. Detonated at -20°F.

G-15

CONFIDENTIAL

CONFIDENTIAL



B31905: Plate No. 17, HEAT No. LL-22104 2-1, Bhn Range 241/255. Rear View. Detonated at -10°F

G-15

CONFIDENTIAL

CONFIDENTIAL



B31906: Plate No. 17, HEAT No. LL-22104 2-1, Elm Range 241/259. Front View. Detonated at -10°F.

G-17

CONFIDENTIAL

CONFIDENTIAL



B31907: Plate No. 11, HEAT No. LL-22104 1-2, Bhn Range 321/321. Front View. Detonated at -20°F.

G-18

CONFIDENTIAL

CONFIDENTIAL



B31908: Plate No. 5, HEAT No. LL-22104 1-1, Bhn Range 351/375. Front View. Detonated at -10°F.

CONFIDENTIAL

CONFIDENTIAL

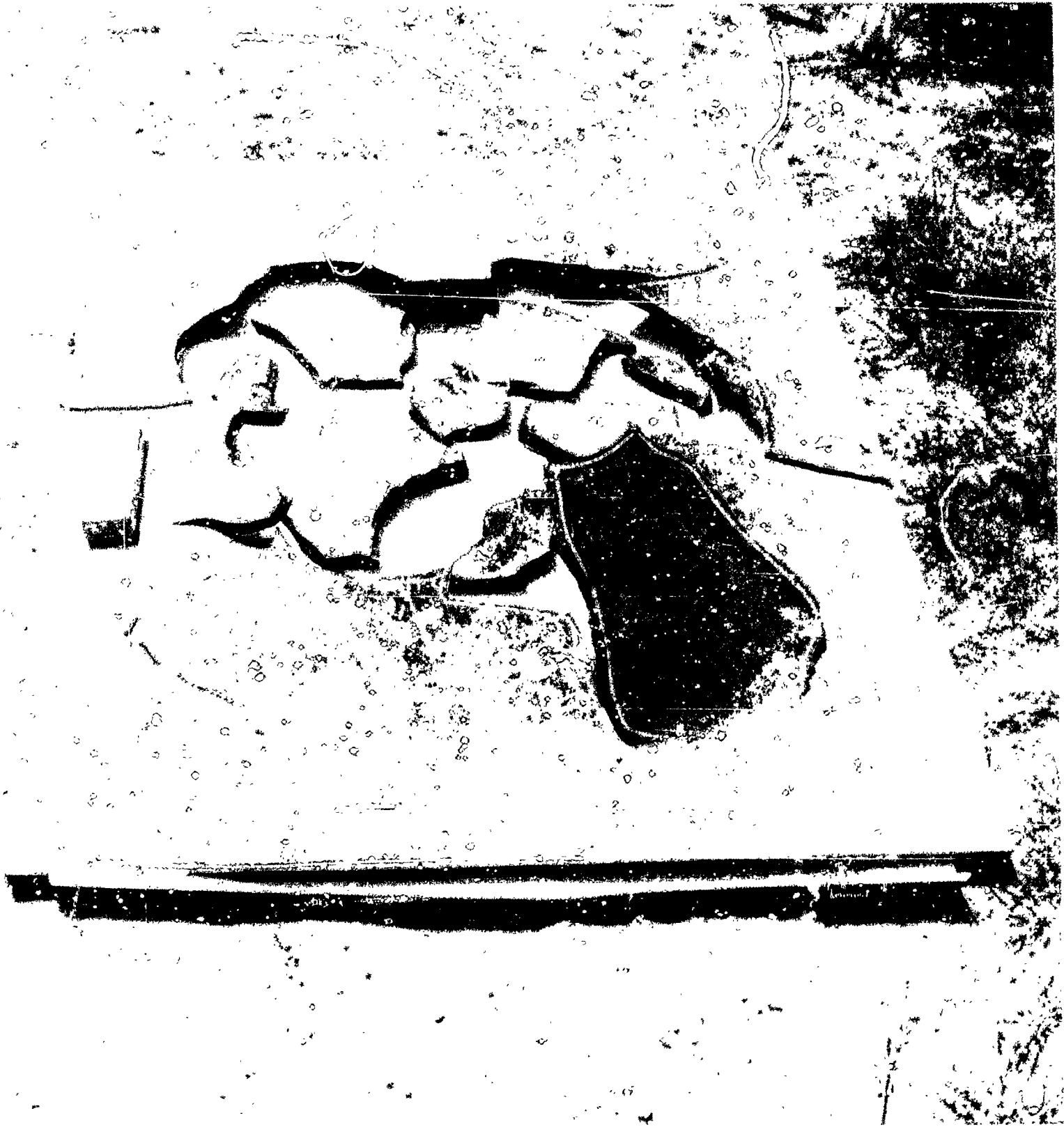


B31909: Plate No. 9, HEAT No. LL-22104 1-3, Ehn Range 293/321. Front View. Detonated at -20°F.

G-20

CONFIDENTIAL

CONFIDENTIAL



B31910: Plate No. 3, HEAT No. LL-22104 1-1, Bhn Range 351/375. Front View. Detonated at -30°F.

G-21

CONFIDENTIAL

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B31911: Plate No. 4, HEAT No. IL-22104 2-3, Bhn Range 351/375. Front View. Detonated at -POPF.

G-12

CONFIDENTIAL

CONFIDENTIAL



B31912: Plate No. 18, HEAT No. 19026 3-B, Bhn Range 292. Rear View.
Detonated at -30°F.

G-23

CONFIDENTIAL

CONFIDENTIAL



B31913: Plate No. 18, HEAT No. 19026 3-B, Bhn Range 262. Front View.
Detonated at -50°F.

G-20

CONFIDENTIAL

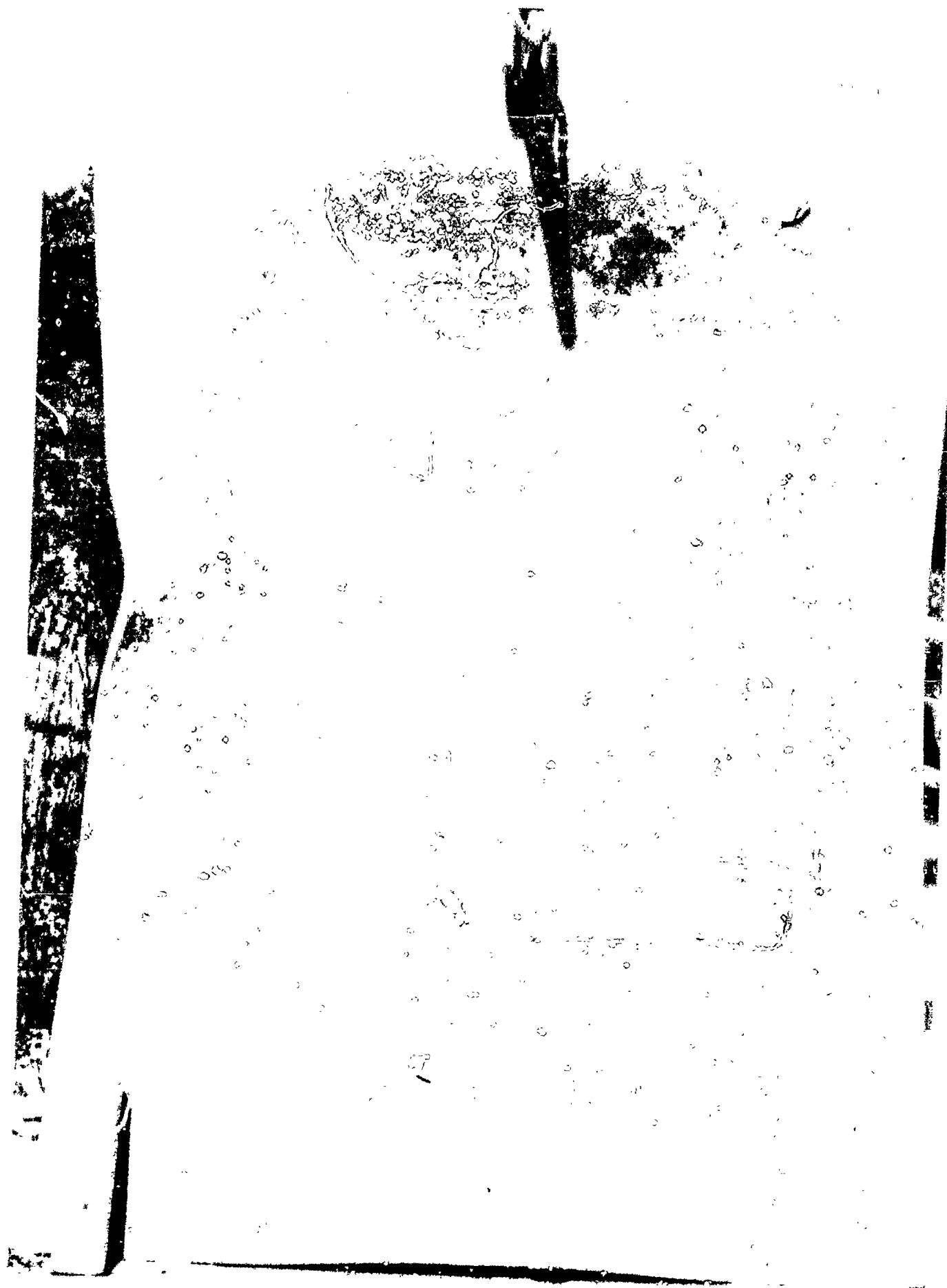
CONFIDENTIAL



B31914: Plate No. 15, HEAT No. LL-22104 2-1, Bhn Range 241/255. Rear View. Detonated at -309F.

CONFIDENTIAL

CONFIDENTIAL



38147: Plate No. 23, HEAT No. 19026 3-B, Ehn Range 252. Rear View.
Detonated at 400F.

G-2

CONFIDENTIAL

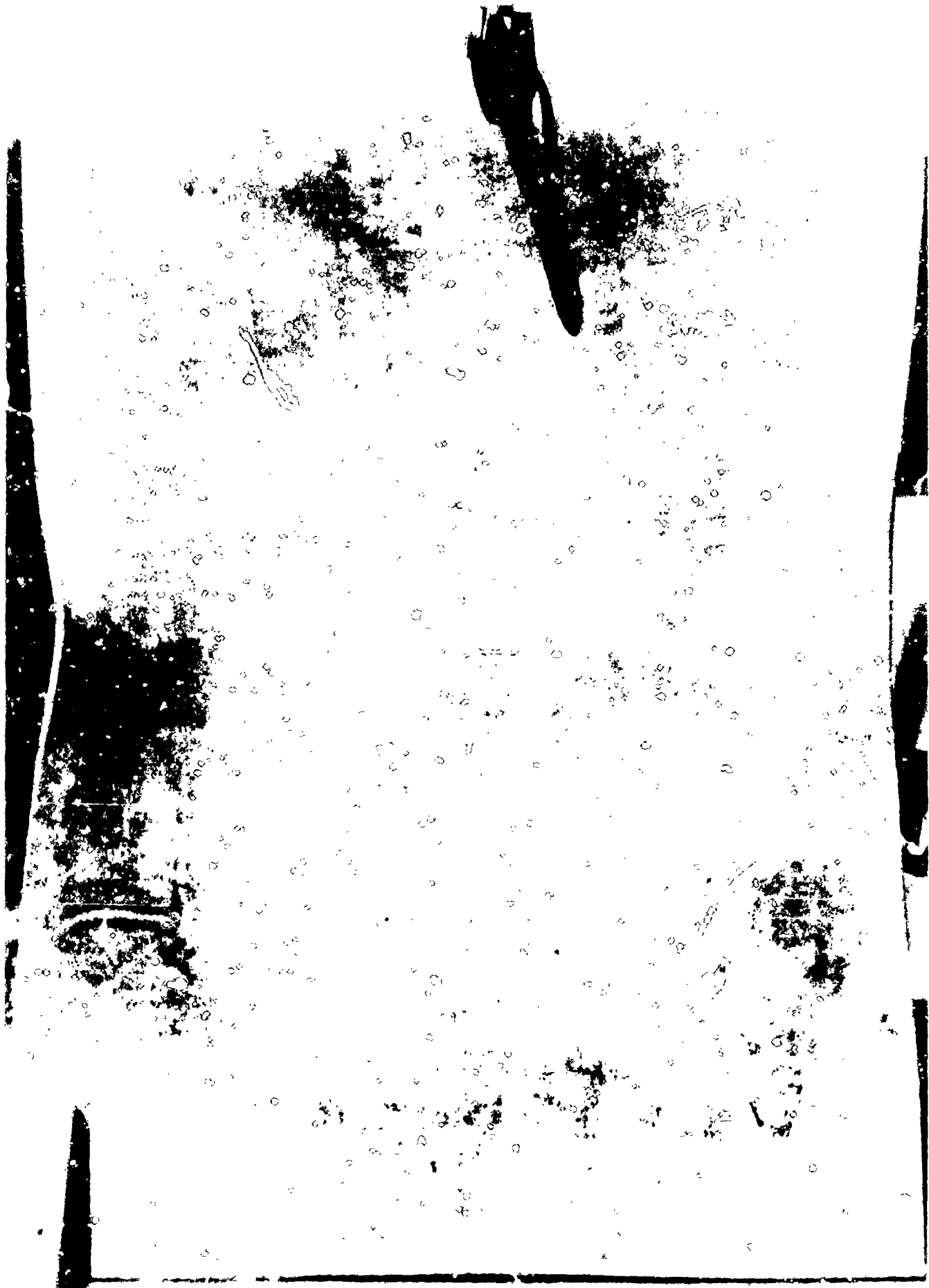
CONFIDENTIAL



F31848: Plate No. 2, HEAT No 19026 3-L, Bhn Range 200. Front View.
Detonated at -300F.

7-7
CONFIDENTIAL

CONFIDENTIAL



B31-40: Plate No. 22, HEAT No. 19025 3-B, Enn Range 252. Rear View.
Detonated at -20°F.

CONFIDENTIAL

CONFIDENTIAL



B31850: Plate No. 22, HEAT No. 10025 3-B, Elm Temp: 200. Front View.
Detonated at -200F.

G-1

CONFIDENTIAL

CONFIDENTIAL



B31851: Plate No. 20, HEAT No. 19025 3-B, Bhn Range 262. Rear View.
Detonated at -100F.

G-30

CONFIDENTIAL

CONFIDENTIAL



E31852: Plate No. 20, HEAT No. 19026 3-B, Ehn Range 62. Front View.
Detonated at -40° F.

G-31

CONFIDENTIAL

CONFIDENTIAL



B31853: Plate No. 13, HEAT No. LL-22104 2-2, Ehn Range 255/255. Front View. Detonated at -20°F.

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CONFIDENTIAL



B31854: Plate No. 13, HEAT No. LL-22104 2-2, Bhn Range 255/255. Rear View. Detonated at -20°F.

G-33

CONFIDENTIAL

CONFIDENTIAL



B31855: Plate No. 12, HEAT No. LI-22104 2-2, Ehn Range 255/255. Front View. Detonated at -30°F.

G-34

CONFIDENTIAL

CONFIDENTIAL



B31856: Plate No. 12, HEAT No. LL-22104 2-2, Bhn Range 255/255. Rear View. Detonated at -30°F.

CONFIDENTIAL

CONFIDENTIAL

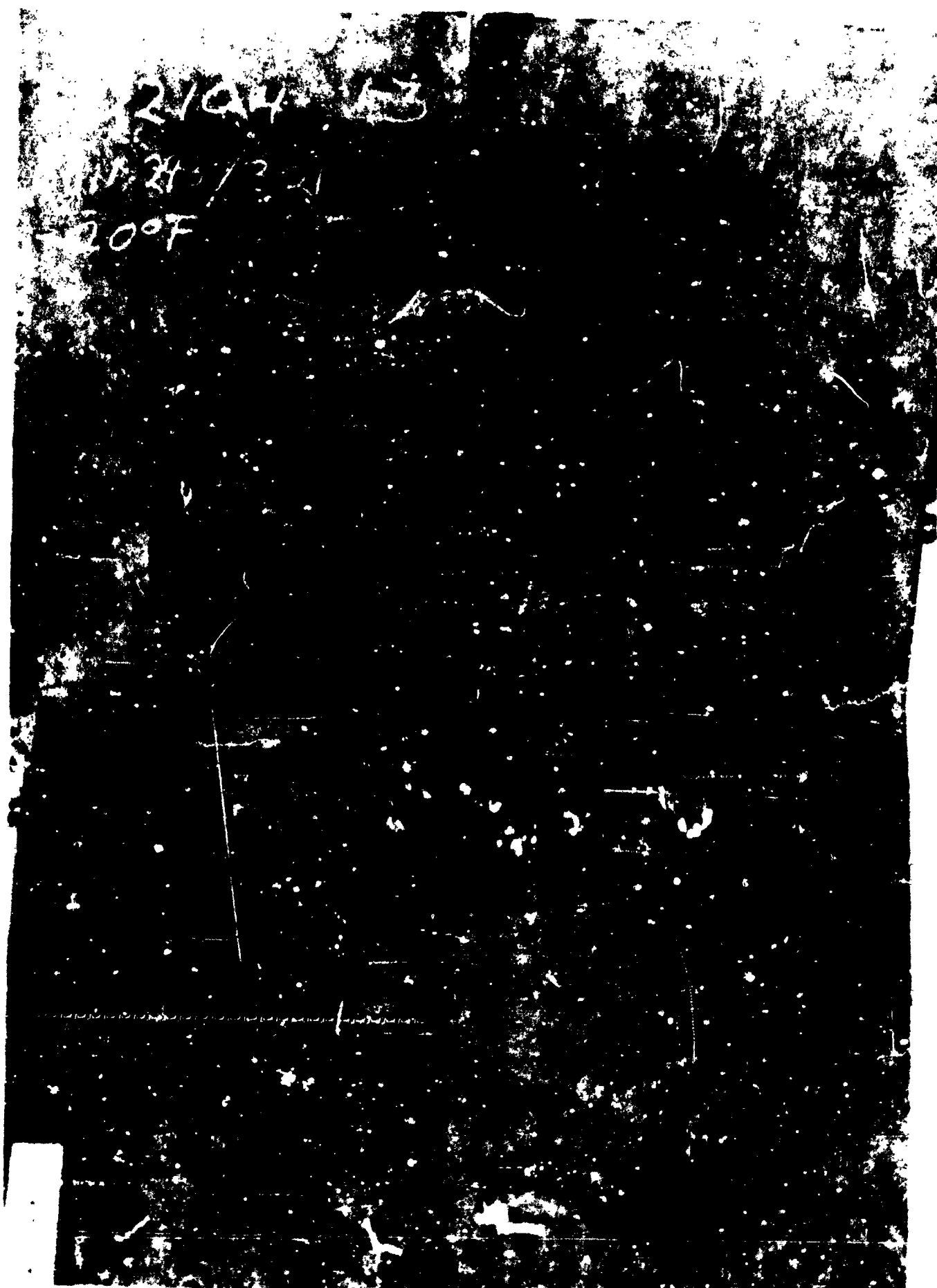


B31657: Plate No. 10, HEAT No. LL 22104 1-3, Bhn Range 293/321. Front View. Detonated at -20°F.

G-36

CONFIDENTIAL

CONFIDENTIAL



B31858: Plate No. 10, HEAT No. LL-22104 1-3, Ehn Range 293/321. Rear View. Detonated at -20°F.

G-37

CONFIDENTIAL

CONFIDENTIAL



B31859: Plate No. 6, HEAT No. LL-22104 2-3, Ehn Range 351/375. Front View. Detonated at 00F.

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CONFIDENTIAL



B31860: Plate No. 6, HEAT No. LL-22104 2-3, Bhn Range 351/375. Rear View. Detonated at 0°F.

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CONFIDENTIAL



B31861: Plate No. 2, HEAT No. LL-22104 2-3, Bha Range 351/375. Rear View. Detonated at -30°F.

G-40

CONFIDENTIAL

CONFIDENTIAL



B31862: Plate No. 2, HEAT No. LL-22104 2-3, Bhn Range 351/375. Front View. Detonated at -30°F.

G-41

CONFIDENTIAL